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TECHNOLOGICAL FORECASTING:

A PRESCRIPTION FOR THE MILITARY R&D MANAGER

by

Marvin J. Cetron

Background. Over the past 5 years, both Government and industry have become fascinated with the potential of technological forecasting as an aid in planning R&D budgets. As laboratories expanded and budgets grew, managers found that many of the traditional ways of allocating their resources of men and money seemed inadequate. But most attempts to build better allocation systems foundered on two basic questions: Which research areas are most likely to be the source of significant technical breakthroughs? Which breakthroughs are most likely to bring an important new development?

The realization that technological forecasting methods could help answer these questions was catching hold slowly when many R&D planners were rudely shaken by a new reality: a leveling-off or even a cutback in most Government-sponsored research efforts. With NASA's post-Apollo projects whittled back, the United States DOD research budgets cut extensively, and other usually expanding budgets on a shorter rein, the need to make hard choices in funding became more critical than ever. Now many planners are turning to technological forecasting to help them make their difficult selections.

In this paper I will explain some of the approaches being examined within the U.S. Department of the Navy as well as some of the directions being actively explored in U.S. industry. The truth is, however, this field is still in an evolutionary phase and most work now being done in one organization cannot be modified enough for adoption in others. At best, what is being done can provide many helpful hints for planners grappling with their own problem of using technological forecasts in allocation problems.[1,2]

It is vital to remember that a technological forecast is not a picture of what the future will bring. Instead, it is a prediction, with a level of confidence, in a given time frame, of a technical achievement that could be expected for a given level of budgetary and manpower support.

The foundation underlying technological forecasting is the tenet that individual R&D events are susceptible to influence. The times at which they occur--if they can occur at all--can be modulated significantly by regulating the resources allocated to them. Another basic tenet of technological forecasting is the belief that many futures are possible and that the paths toward these futures can be *mapped.*[3]

In use, a technological forecast can be looked at from two vantage points. One, in the present, gives the forecast user a view which shows the path that technological progress will probably take if it is not consciously influenced. In addition, the user will see critical branch points in the road--the situation where alternatives futures are possible. He will also gain a greater understanding of the price of admission to those branching paths.

The second vantage point is in the future. The user selects or postulates a technical situation he desires. Looking backward from the point, he can then discern the obstacles that must be overcome to achieve the result he wants. Once again he is brought up against the hard realities of what he must do to achieve a desired result. As one user has said: "The process substitutes forecasting for forecrastination."

Making Basic Forecasts. At this point it is worth reviewing some of the basics of making technological forecasts. Let me hasten to say that the idea is not new. Leonardo da Vinci is probably the prime example of the scientific and technical forecaster whose knowldege and imagination enabled him to foresee many developments far in the future. Science fiction writers from Jules Verne to Arthur Clarke have also peered into the fnture, often with great success.[4] As long as one remains within the general bounds of knowing natural laws, he is safe in forecasting almost any technical achievement and enjoying some success. But a highly developed imagination offers little help for the technological planner--the odds aren't good enough.

To reduce the odds, most technological forecasts, today, fall into four categories: intuitive, trend-extrapolating, trend-correlating, and growth analogy.[5]

In intuitive forecasting an individual may make an educated guess, or he may call on polls or panels of experts for advice. A technique which promises to produce more objective intuitive forecasts is the Delphi method, developed by Olaf Helmer of the Rand Corporation. In one version, a group of experts in a chosen field might be asked to name technical breakthroughs or inventions urgently needed and realizable within the next 50 years. The experts are polled by written questionnaires, eliminating the open debate generally found in panel decisionmaking. As a result, the influence of certain psychological factors is reduced: a persuasive speaker, unwillingness to abandon publicly expressed opinions, or the bandwagon effect of majority opinion. In a second round of questionnaires, participants are asked to give a time scale for achieving each of the items selected. They are also asked the reasons for their earlier opinions. These data are correlated and fed back to each with a request that he reconsider his earlier beliefs and submit new estimates. The result is usually some sort of a consensus.[6]

The strength or weakness of Delphi or other polling systems rests upon the knowledge or intuition of selected experts. It assumes that the consensus estimate is generally correct without an examination of basic data. Most other forecasting methods are tied directly to basic technical data. The trend extrapolation technique, for example, is based on two fundamental assumptions: (1) the forces that created the prior pattern of progress are more likely to continue than to change; (2) the combined effect of these forces is more likely to extend the previous pattern of progress than it is to produce a different pattern.

One difficulty in using this technique, however, is that the longer the period of the forecast, the greater the probability that one or more of the assumptions made will become invalid. The yield strength of a material, for example, will go up as its density is increased, but there is a theoretical limit.

The trend correlation method, on the other hand, uses two or more identifiable trends in a technical field and tries to determine the probable relationship of one to the other. Plotting the speeds of military and transport aircraft indicates that the transports lag by a predictable amount. Therefore, looking at current--or future--military aircraft gives a good insight into the future of airliners.

Finally, forecasting by growth analogies recognizes that progress in a specific technical development has an exponential characteristic initially, then changes its slope and tapers off toward a horizontal asymptote. This approach, however, is good only for a short term--10 years at the most. In many cases a new development will take over the improvement rate as the old one is running out of steam. Mercury vapor lamps, for example, started improving dramatically just as incandescent lighting had reached its limit.

The four techniques discussed have one common aspect: They depend on historical data and projection. There is no provision in them for the systematic introduction of management plans and actions. To take these into account, the forecaster must still rely on intuitive judgment. Newer and more sophisticated attempts at forecasting, however, include a systems analysis and a mathematical modeling approach. Basic to these methods is the interaction of human awareness of economic, social, and geopolitical needs with the technical state of the art. The technical inputs are formulated by methods like those mentioned above, but they are then examined for nontechnical feasibility.

Putting Forecasts to Work. In most cases a manager does not have a total system to work with. Instead, he has the results of trend extrapolations or other regular technological forecasting projections. How does he use these data? While there are many approaches, the following is one which the Navy Department is examining to determine which techniques can best help decide which R&D projects to fund.

We begin with a technical planning flow chart (figure 1) that shows the "shredding out" of all the bits and pieces that comprise the makeup of a new vehicle. Assume that we have a technological forecast for each and every parameter of the shred-out. The forecasts, at each level of the breakdown, are the probable paths that various technologies will take. Armed with this type of data, a meaningful discourse can ensue between the user and producer. For a given set of operational requirements and performance characteristics called for by the user, the technical planners can respond with data that tell the user by what alternative means his needs can be satisfied, and when he can expect these to be accomplished. Many of the trade-offs--between steam, diesel, and nuclear energy, for example--become clear.

Operations officers, however, are not fully quite so acquiescent in accepting what a planner sees ahead. When faced with a military threat, or an anticipated threat, they want an effective answer to that threat by a specified date. The same holds true if they wish to create a new force of their own. In these situations, planners are taking a vantage point at some time in the future and are trying to discover if they will have the technology they need by that time.

Quite likely an examination of the technological forecasts to that point in time will reveal that the users are not likely to get what they want. Now, this is useful information in itself, and represents an approach that is not yet widely used in industry.

However, this view of the technological forecasting task is not the only one. There is the question of which path we should take to achieve a desired result. By deciding on our needs in the future and looking at the forecasts, we can spot the principal obstacles standing in our way and the magnitude of those obstacles. The inference is clear: if the given goal is to be achieved in a given time, the efforts must be applied in the areas containing the major obstacles. Or, we can settle for something less with clear knowledge of what that something less will be. Often, this analysis will show that two or more paths may be taken to achieve the needed or acceptable capabilities. The point here is that an environment of flexible choice is engendered--choices of which the user was not previously aware. A truly comprehensive technological forecast is backed up not only by material and data which were used in generating the specific forecasts but also by supplementary analysis of various subfactors that could influence each technological forecast. Forecasts like these help indicate the future posture of an enemy or competitor. While you don't know what he *will* do, you at least have a better idea of what he *could* or *could not* do.

Mechanics of Decisionmaking. Now let's turn to an example and see how a specific decision can be analyzed, based on the forecasting techniques utilized at the Annapolis Division of the Naval Ships Research and Development Center.[7] Forecasts for ship propulsion systems are given in terms of specific weight, reliability, noise, et cetera. The next level of consideration takes us into the area of subsystem segments--transmission, energy converter, thrust producer, et cetera. Each of these key into an associated set of parameters which, in turn, key into specific forecasts. In this fashion, we can work our way down the chart, (figure 1), eventually going into any degree of detail we wish.

This information is used for very practical decisions. Marine gas turbines, for example, have a tremendous potential for development. The possibilities for highpower, lightweight, compact power plants are unmatched in any other type of unit. These characteristics are particularly vital for powering new-concept vessels such as hydrofoils and air-cushion craft. In the last few years there has been a rapid growth in the horespower capacity of gas turbine units. Engines as large as 43,000 horsepower have been built, and units exceeding 50,000 horsepower are projected. This growth trend will probably continue but at a lesser rate as limitations of mechanical, thermal, and ducting size are approached. However, much larger power outputs will be built by using multiple gas generators to drive a single turbine engine. Power outputs as high as 150,000 horsepower have already been attained by this method. The R&D manager's problem is to decide which aspects of turbine development are most critical.

The development trends for the specific weight, volume, and fuel consumption for a simple cycle gas turbine are shown in the graphs (figure 2). In all of these the trend correlation (lead-follow relationship) was used in the study. Aircraft gas-turbine technology has been the leader not only because of the greater aircraft speed payoff, but also because the marine environment led to problems of corrosion. Now that materials and other problems are being overcome, the curves are coming together--the aircraft experience gives some indication of what can be expected in future naval turbines.

As shown in the efficiency graph in figure 2, the compressor, combustion, and turbine efficiency have reached a plateau according to a growth-analogy study. Any future improvement will be limited. Consequently, these component efficiencies will have an insignificant effect on future engine characteristics.

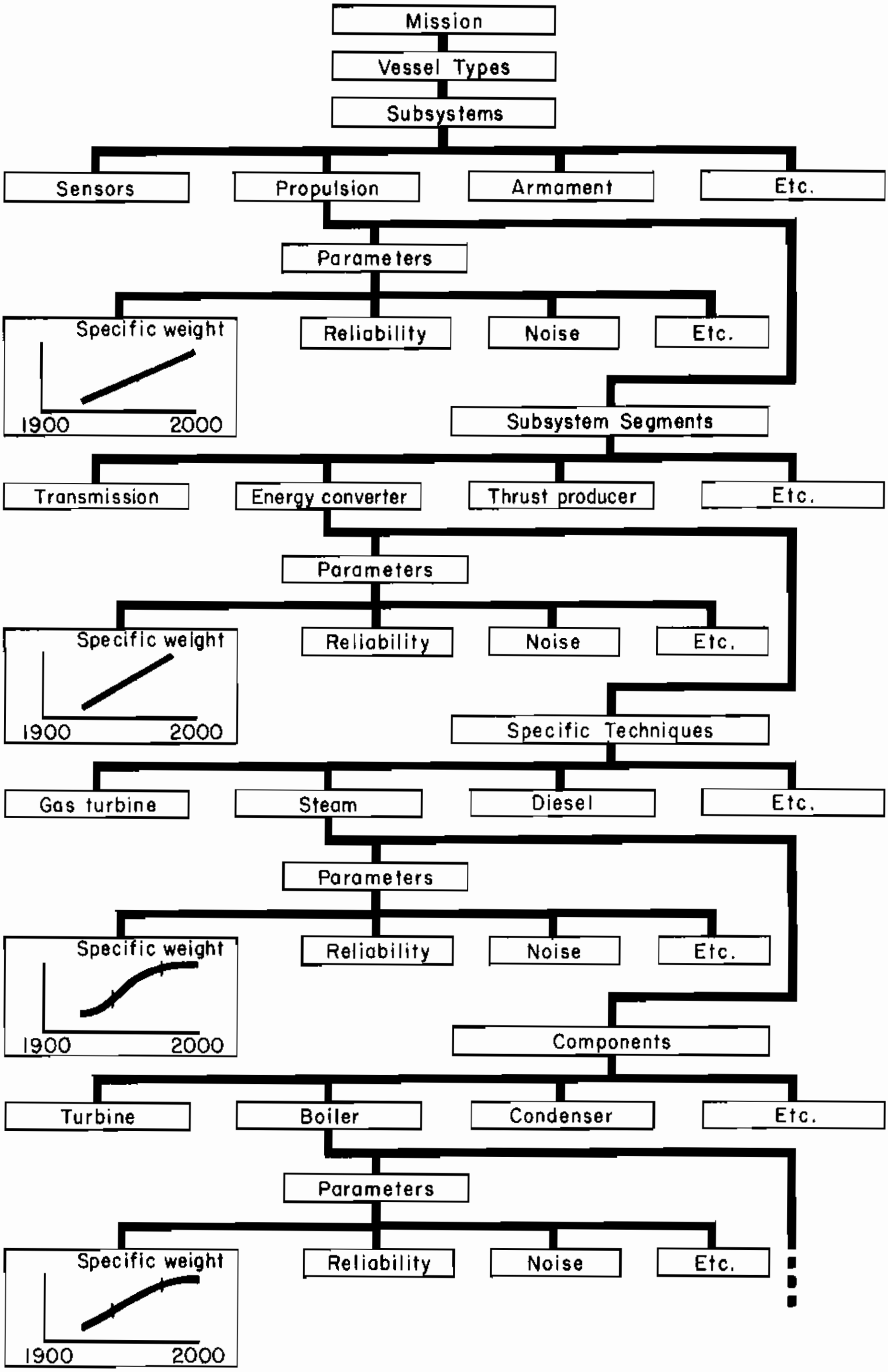

Fig. 1--Technical Planning Flow Chart

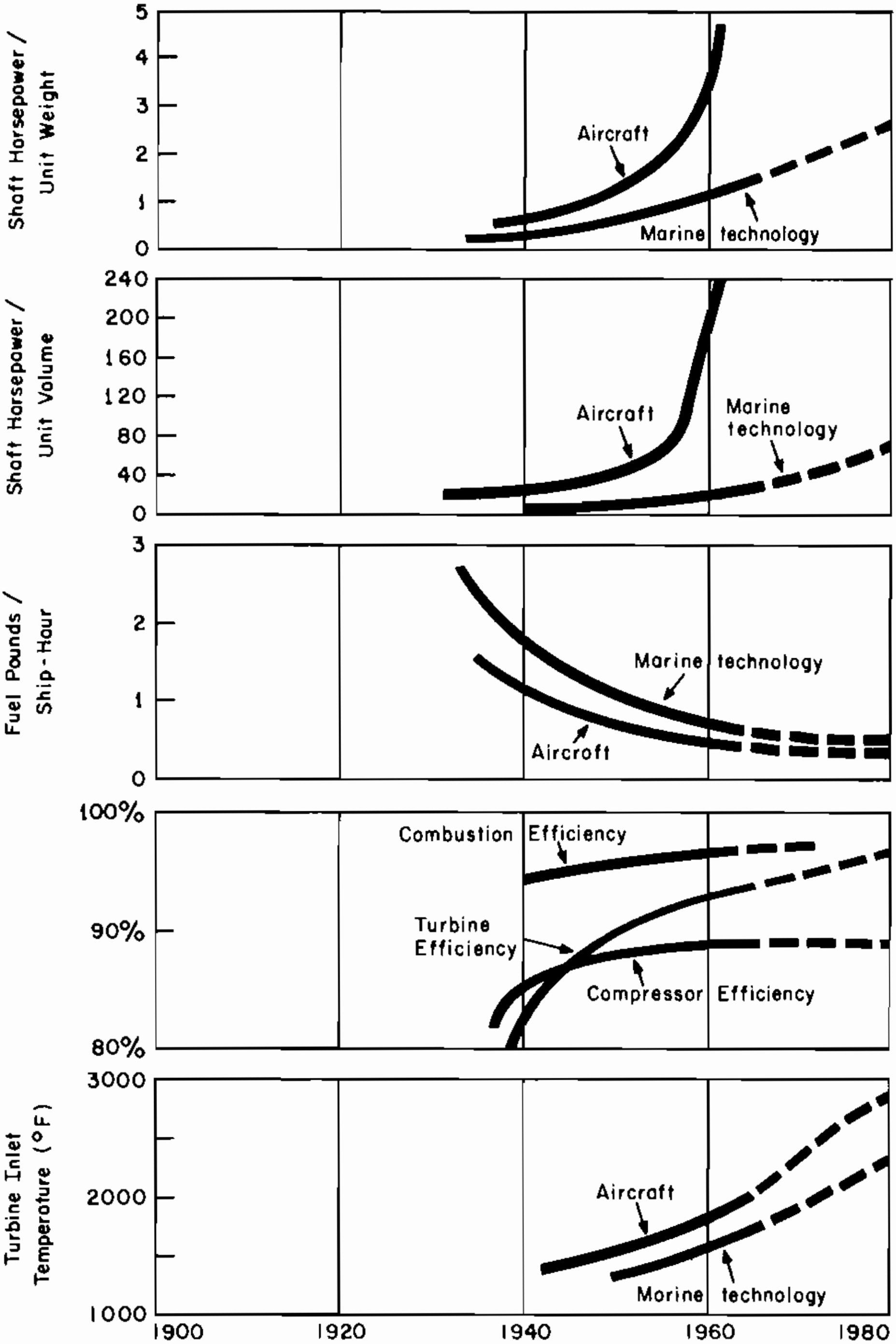

Fig. 2--Gas Turbine Characteristics

Recent improvements, moreover, have resulted from an increase in the compressor-pressure ratio. But any further increase will be small. Because of improvements in blade loading, compressors are now designed to an optimum pressure ratio determined by turbo inlet temperature. And this blade loading, which has enabled engines to obtain higher pressures with fewer stages, appears to be approaching a limit.

This combination of forecasts shows that the addition of more heat energy within the same basic engine configuration--the major contributing factor to recent engine improvement--is likely to be the key factor in future improvement. Extrapolation of the curve to temperatures in excess of 2500° F is based on laboratory tests in which operating temperatures as high as 4000° F have been achieved--another trend correlation forecast.

As a result of this forecasting approach we now know where our R&D efforts should be concentrated. These are the high payoffs:

(1) Cooling of turbine blades and other components in high-temperature ambients. This will allow higher turbine inlet temperatures.

(2) New materials and protective coatings for these high-ambient components. This will increase high-temperature capabilities by increasing resistance to high-temperature oxidation and sulfidation. An increased resistance to thermal fatigue and creep is also required.

(3) Improved materials designs, and fabrication techniques for regenerative gas turbines to reduce their cost, weight, and bulk.

(4) Further application and adaption of aircraft gas turbines and technologies to ships.

(5) Attempts to improve efficiency of combustion, compressor, and turbine.

(6) Attempts to increase significantly the blade loading or compressor-pressure ratio if accompanied by major design changes.

The Overall Picture. Up to this point we have been discussing the technological forecasting needed for one problem in a laboratory. But any organization has many such problems.[8] Here the question becomes one of allocation of resources of men, money, and materials. The evaluation scene therefore shifts from the technical specialist to the department manager, the head of research, and the overall planners. The forecast data must be fitted into their overall planning approach if it is to be really useful.

When management problems are simple, a decisionmaker can examine the various factors he must consider with relative ease. One man, such as the hermit in a cave, the individual homeowner, the small businessman, or the teacher in a one-room school, may be able to interrelate all of the necessary information and succeed in his endeavors.

As the management scope becomes larger and the complexity of problems increases, more and different factors must be considered to reach a decision. Soon, staff and management procedures are needed to assist in all phases of management. Eventually, the point is reached where any one decision affects many facets of the operation; all efforts become interrelated to an alarming degree.

Increasing complexities are particularly true with programs or projects which must operate within a fixed government or corporation resource ceiling. Choices must be made on alternative approaches, specifically, which efforts should proceed and which should be dropped or delayed. Since numerous efforts are interrelated in time, resources required, purpose, and possible technical transfer one to another, choices must be made with consideration of the total effect. Whether he be a manufacturer, a service industry director, government administrator, or university professor, every manager seeks the greatest payoff for resource investments.

What alternatives does a manager have for developing resource-allocation approaches? The resource allocation problem is usually too big to keep in one man's head and often inputs come from levels completely outside of his control. Hundreds of inputs can be involved when the alternatives are examined in depth.

A familiar resource allocation approach is termed the *squeaking wheel* process. One can cut resources from every area (one can be sophisticated and cut some areas more than others) then wait and see which area complains the most. On the basis of the loudest and most insistent squeaking, the manager can then restore some of the resources previously withdrawn until he reaches his ceiling budget.

Another common approach develops the minimum noise level and results in fewer squeaks by allocating this year's resources in just about the same manner as last year. The budget perturbations are minimized and the status quo maintained. If this *level funding* approach is continued very long within a rapidly changing technological field, the company, group, or Government agency will end up in serious trouble.

An effortless version of the preservation of management security approach to resource allocation seeks to perpetuate the *Glorious Past.* Last year, or the year before, or perhaps several years ago, a division or organization had a very successful project, therefore why not fund the unit for the next 5 years on any projects that they advocate? The premise is "once successful, always successful." This method really means that no analysis should be made of the proposed project or its usefulness; instead, projects will be assigned resources solely upon the basis of past record of an individual or organization.

Still another way to allocate resources is called the *white charger* technique. Here the various departments come dashing in to top management with multicolor graphs, handouts, and well-rehearsed presentations. If they impress the decisionmaker, they are rewarded with increased resources. Often the best speaker or the last man to brief the boss wins the treasure.[9]

Finally, consider the *committee approach,* which frees the manager from resource allocation decisions. The committees tell the manager to increase, decrease, or leave all allocations as they are. A common danger is that the committee may not have enough actual experience in the organization or sufficient information upon which to base its recommendations. If the committee is ad hoc or from outside the organization, the members can also avoid responsibility in not having to live through the risky process of implementing their recommendations.

Obviously, the described allocation methods are neither scientific nor objective, though they are utilized quite extensively. These naive approaches point up the need of the manager and his staff for an aid to bring information into a form upon which judgment may be applied. It is a common experience for an organization to have numerous reports on specific technical subjects which recommend increased resources for the particular area. But the direct use of this data only compounds the manager's problem when he tries to allocate resources among the many technical areas. If he is operating under a fixed budget ceiling, to increase funding for one technical area requires that either one or more technical areas must be correspondingly decreased.

Technological Resource Allocation System. A more sophisticated alternative approach involves the use of staff or specialists in operations research. Information they assemble can be used to significantly assist managerial judgment. This is the point where quantitative evaluation techniques enter the picture. Each major aspect of a program can be examined, first separately and then as its is interrelated to competing factors. Items such as timeliness, cost utility or payoff, confidence level or risk, personnel, facilities, et cetera, can be evaluated by specialists in each field and the total picture made available as a basis for decision. Greater payoff areas can be identified, and problems can be highlighted. Inputs can be accurately recorded, made clearly visible, and analyzed for assisting the final decision.

The use of quantitative techniques permits input factors and possible outcome to be reexamined readily and different managerial emphasis applied. The manager can still hedge his "allocation selections" by allocating resources through such criteria as increased resources to previously successful groups, backing a high-risk effort--i.e., a high cost project with slim chances of success which might yield gigantic results. The decisionmaker can incorporate any desired additional criteria--such as the politics of selection, competitive factors, or technological barriers.

The question now becomes one of allocation of the resources of men, money, and materials. Figure 3, the long-range planning diagram, which is really a broad allocation diagram, shows the interactions of numerous managers from the technical specialist to the department manager, the head of research, and the corporate planners. The data must be fitted into an overall planning approach if it is to be really useful. Corporate goals are the main topic and occupy the central position in the chart. In order to establish corporate goals, the preliminary steps of systems analysis, needs analysis, and deficiency analysis must be accomplished. After the goals and technical objectives are established, technology assessment and R&D Programming take place to complete the R&D resources allocation process. Each of these steps will be explained in greater depth.

System Analysis. Corporate policy must be considered and involves philosophic and strategy questions, including these: Shall I be the industry leader? Shall I keep abreast of the industry technically and see if a major market develops? In the overall environment, competitors' actions must be followed closely, but there are other factors such as interest rates, business expectation, economic forecasts, et cetera to be identified.[10] Figure 3 viewed as the corporate planning chart, shows a recommended organization of considerations.

The technology forecasting element acts as a catalyst in setting and implementing overall corporate goals. At present only a handful of the largest corporations are really utilizing their full corporate technical potential. The next question is how to relate the technological forecasts with appraisal in this total picture. A discussion of the numerous appraisal methods would be a long story in itself. For example, all systems employed by the Department of Defense utilize three major factors in the appraisal or normative forecasting process: military utility, technical feasibility, and financial acceptability. Each of these factors is amenable to quantification and can be fitted into a model which compares the value of each component project or system. Due to the complexity of the analysis, it is necessary to program the job on a computer to get usable information quickly. It must be remembered, however, that these computer processes are simply a tool to aid the decisionmaker; the machine merely arranges the material in accordance with his instructions so that he can quickly focus his attention on those areas which require his special knowledge and judgment.

The environment (competition, climate) also must be considered and

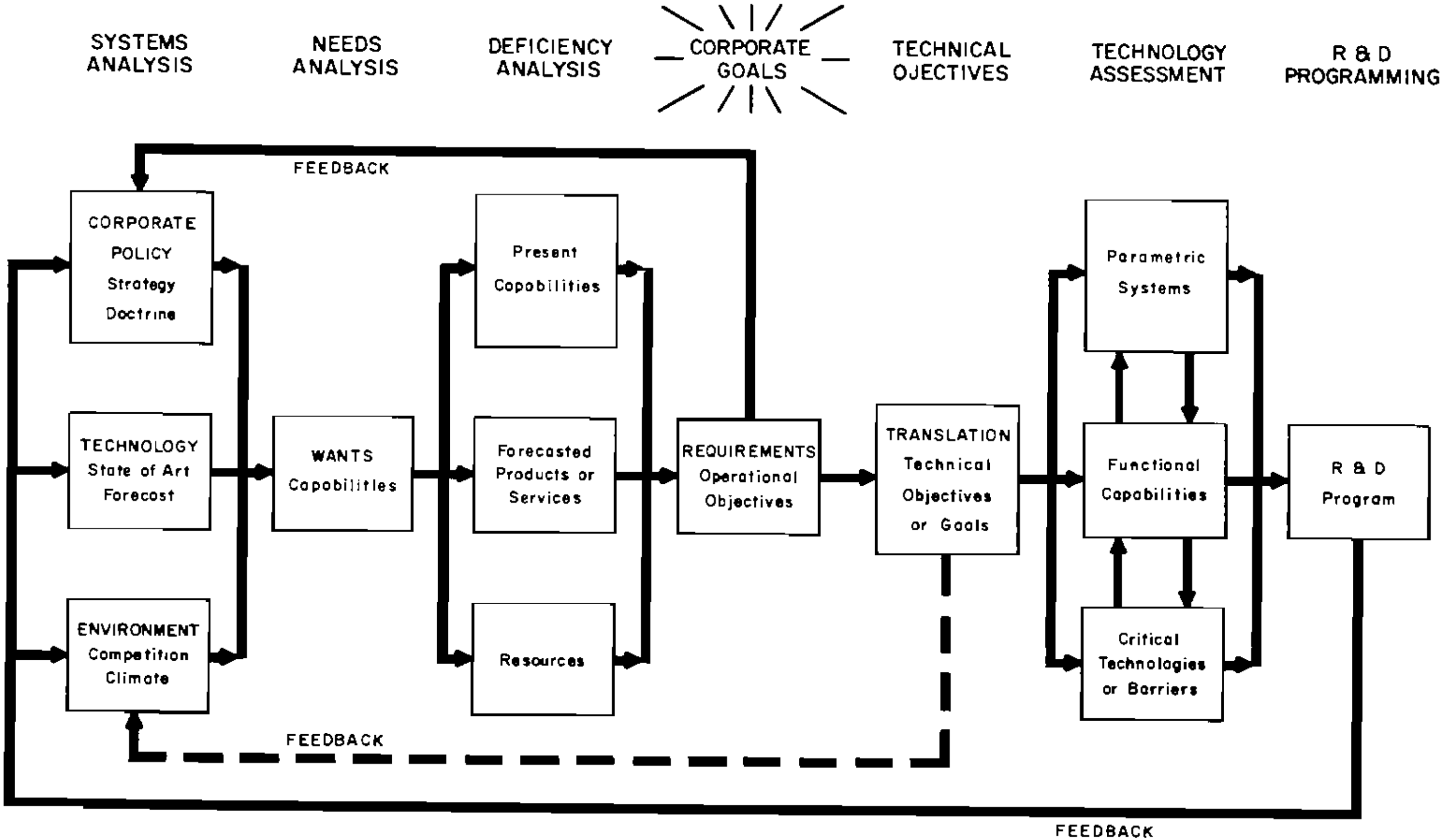

Fig. 3—Long-Range R&D Planning

includes such questions as: Who are the competitors? What unique skills, products, or finances do these competitors possess? What is the industry-wide climate? Will the industry demand continue to expand rapidly, will there be a sudden drop in demand, or will a leveling of demand be expected. The factors considered under the systems analysis allow the needs (wants) as well as the unique or strong capabilities of the firm to be identified.

Need Analysis. Analysis of the wants or desirable areas of growth for the firm is equally as important as defining the areas where no growth or decline is expected.

The national or international economy provides the broadest scope for analysis of the needs for the firm's products or services. The stage of development in the country, the requirements from related industries, the availability and cost of capital and governmental controls may all require attention for the process of determining what the firm "wants" to do.

The industry share-of-the-market for the firm relates directly to its volume. That is, in an industry of rapid growth the individual firm may grow while remaining constant relative to its competitors. Conversely, the share-of-the-market may need to be greatly increased to remain at a level stage in a declining industry.

Finally, the desire of the firm and of the individual groups within the firm can be assessed. However, these desires may not be attainable within the capability of the firm. Thus, the wants need to be balanced against the firm's capabilities.

Deficiency Analysis. After the wants of the organization have been established, the capabilities available must be delineated in order that areas of deficiency can be identified. Ordinarily, the present capabilities of an organization will be known, but often effort is required by management to obtain a comprehensive statement of its technological capabilities in terms of men, money, and machines. Because we are dealing with futures, the products and services such as new manufacturing methods, new materials, and advanced skills that are forecasted to be available must also be carefully identified. Other resources available to the organization will also be important information. Skills or manufacturing processes or equipment, et cetera may exist that could be available from outside the organization when and if required.

By identifying and analyzing the present capabilities, forecasted products and services along with other resources available, the deficiencies and excesses will become evident. The analysis now permits management to focus upon realistic corporate goals.

Corporate Goals. The most important phase of the resource allocation system may now be brought into focus --the corporate goals (objectives). These goals may be viewed by top management from the wants (desires or needs) of the organization which have been carefully considered for feasibility against the present or potential capabilities of the organization. Several passes through the analysis described above usually are required before acceptable goals are achieved by top management.

These corporate goals will be translated into requirements for performance of the organization, or as operational objectives.

Technical Objectives. The idea of applying quantitative approaches to resource allocation has too long been suspect by management. Currently, both industry and government are seeking tangible improvements in the results from use of available resources. Economy drives and or cost/benefit analyses have resulted in pared budgets with the need more critical than ever to make hard choices among alternatives programs. The application of objective measurements to resource assignments has too long been classified as visionary and impractical.

For example, how does a corporation decide whether its allocation this year for research and technology is adequate? And how does it decide the right balance between the research and development or manufacturing projects?

A prime example of lack of quantitative data exists in the area of assessing technological effort. Querying the scientist or engineer and requesting a justification of his selection of a program or a task (including projected benefits to a mission or product-oriented organization) has often been construed as an assault against the scientific professionals' prestige and prerogatives. Today, scientists and engineers are beginning to realize that they are accepted at the highest organization levels and that one of the signs of this ascendancy is their high visibility and responsibility to the interrogation of criteria and rational judgments. The technical manages intuition can no longer be accepted as infallible and beyond managerial review [11]

Several project evaluation and selection techniques have as their basis a belief in the efficacy and acceptance of Bayesian statistics and theories of probability.[12,13,14] Bayesians believe that it is correct to quantify feelings about uncertainty in terms of subjectively assessed numerical probabilities. Thus, assessments are made of probabilities for events that determine the profitability or utility of alternative actions open to the decisionmaker.

For example, there is a necessity to assess the criterion of whether a piece of research is technically feasible (technological forecasts) or what is the probability that it will be successfully accomplished (level of confidence criterion). Bayesian theory believes that it is possible for an "expert" in the field being assessed to assign a figure of merit or "subjective" probability number that the event will actually occur. This theory states that on this very subject matter an expert can assign a "subjective" probability number from a scale, for example, between 0 and 10. Men of considerable experience in a field usually have no difficulty in utilizing a Bayesian probability scale. In a like manner, other criteria, such as the utility of the research to the objectives of the organization, or relevance to desired priority systems or corporation products, are assessed (criterion of utility).

The use of Bayesian subjective probabilities makes feasible the incorporation into the decision process, in a formal and visible way, many of the subjective and objective criteria and variables previously taken into account by the decisionmaker informally and without visibility.

The probability assignment, a number between 0 and 10 to each facet, factor, criterion, or parameter inherent to a rational decision, reflects the degree of belief held by the individual expert(s) that the above objective will be met.

Thus the experience, knowledge of the subject, and judgment of the various experts are summarized by the subjective probabilities that they assign against the respective criteria. The final or top decisionmaker then has a clear view of the alternatives and can use the results of the probability assignments of the different experts. A computer can be used to summarize the choices or probabilities of the experts. The computer can also be used to determine "consequences" if the probability assignments are changed or if the final decisionmaker adds new information or weighting factors, et cetera.

Advocates of allocation and selection procedures are accused of assuming that the myriad of quantitative estimates of scientific relevance, importance, feasibility, and the like should and can be collected and manipulated.[15] Apparently the academic community also believes in the above assumption. For example, in the field of education, the university admission policy is based on a "myriad of quantitative estimates."

Mr. Robert Freshman, one of the U.S. Air Force Laboratory planners who was previously a professional educator, relates the following example.[16] High school students are admitted to universities based on the quantitative judgments of teacher grades as the key criterion. These teachers grade about five subjects a year, for 4 years of high school--thus, 20 teacher judgments. Different teachers, different subjects, different tests, different subject matter taken in high schools throughout the nation are fused into one. Teacher opinions on how to grade, biases and prejudgments, oral recitations, grades on nonstandardized, unstructured subject matter and tests are all injected into the above conglomeration to form the individual teacher's final grade in one subject.

High school grades for the 4 years are averaged to come up with one number--the high school average--the magic number which has great influence in college admission. More miraculous is that there is a good, positive correlation between this magic number and success in college. It is recognized that this "quantitative estimate" of many judgments is the best single criterion or indicator of success in *college;* but again it is just an aid to the decisionmaker. The personal interview, college boards, or extracurricular activities also affect his judgment prior to making a final decision.

Opinions and judgments can be and should be weighed by every decisionmaker in his final decision. Several quantitative techniques gather and summarize the opinions and judgments to enable the final decisionmaker (like the university dean of admissions utilizing teacher judgments) to visualize and weigh, as one input to his decision, the judgments of numerous people on diverse factors.

Two main points on quantitative decisionmaking should be emphasized:

(1) The quantitative management techniques discussed *do not make decisions,* but provide a basis of information upon which decisions can be made.

(2) A validity check can not be made since once the resources are allocated, the plan becomes self-fulfilling.

Subsystem Analysis or Technology Assessment. Assessment of technology or subsystem analysis is employed to answer the question: which, when and how many resources should be allocated among the alternative projects? Since the topic is multifaceted it is necessary to draw information from a variety of sources including operations research, project selection techniques, and technological forecasting.

Technology assessment is not official jargon. The expression "assessment of technology" is not found listed in the table of contents or indexes of texts on management. Nor is it identified and found in the general literature of management or in official planning, programing and policy documents of the Government agencies.

Assessment is commonly considered to mean "setting a value to." Assessment of technology, then, means setting a value to technology. Technologies include areas of special knowledge such as gas turbines, diesels, thermionics, thermoelectrics, fuel cells, and energy conversion as opposed to the areas of science which include items such as alloy theory, surface physics, cryogenics, and magnetism. The kinds or measures of value attributed to technologies will be discussed later. Also, it can be demonstrated that the nature of the assessment of technology depends on who assesses, why the assessment is performed, and the nature of the technology itself.

How is Technology Assessed? One simple technique of assessing technology uses an analogy and a rather trivial example. To assess the value of two baskets of fruit with contents as listed in table I, first assess or determine the value of the baskets in one of many respects such as weight (a critical criteria for submarines), volume (a critical criteria for spacecraft), calories (a critical criteria for weight-watchers), and cost (a critical criteria for budgeteers). For this example, assessment can be readily done in terms of financial cost with monetary cost values assigned to the individual items as follows:

10 cents per apple
20 cents per orange
30 cents per banana

Value (#1) = (5 x 10) + (8 x 20) + (6 x 30)
= 50 + 160 + 180
= $3.90

Value (#2) = (10 x 10) + (2 x 20) + (9 x 30)
= 100 + 40 + 270
= $4.10

The analogy is made by having the baskets of fruit represent technologies, the fruits to represent characteristics of parameters of the technologies, and the cost values of the fruit to represent their "relative importance factors." The value for each basket can be represented by the formula:

Value = summation of [(relative importance factor) x (criteria or parameter)]

This illustration introduces the terms "importunce factors" and "parameters" and demonstrates (assuming the analogy is valid) that the parameters, while different from each other, provide measures of technology that can be taken collectively to determine a single numerical value which can be compared to a similarly derived value of another technology. Note again that the assessment could have been made for the purpose of comparing other importance factors--values of weight, volume, calories, et cetera. It is easy to see that the selection of the relative importance factors is dependent upon the parameters (kinds of fruit, in the example) and upon the purpose of the assessment. This latter dependency will be discussed further in addressing the question: Why (or for what purpose) assess technology? Please note that the above example does not add together apples and oranges, rather, importance factors have been constructed so as to cancel the different units of fruit in the multiplications and does add like units of cost associated with each different fruit.

Another *hypothetical* example of technological assessment is provided by Keith Ellingsworth of the Annapolis Division of the Naval Ship Research and Development Center, Division Planning Office.[17] This one is not in the form of an analogy nor is it trivial. It concerns the design of a boat for river warfare use in Vietnam. The design has proceeded to the point where a choice must be made between two parameters of two boats, as illustrated in table II.

The two boats respectively have speeds (knots) and noise levels (decibels) of 25K, 80db and 20K, 50db. Here it appears difficult to assign relative importance factors, but there are methods which can be used. In this case a mission analysis can allow us to determine the relative importance factors. Imagine the boat patrolling a river "looking" up and down the river with its radar. Its mission is to prevent enemy junks from crossing the river. The more noise the boat makes, the further up the river the enemy can hear the boat. The farther away the boat can be heard, the more time the enemy has to escape by crossing the river or by ducking back into a shallow creek where our boat can't go, and the faster our boat must be to catch the enemy. It is simply a matter of physics and geometry to determine, say for a given boat noise, the speed required to achieve a stated level of mission effectiveness. The results of a mission analysis might be stated as for every 16 decibels of noise, 4 knots of speed are required in order to be able to intercept those junks up to a mile away and in the middle two-thirds (width) of the river. In other words, 4 decibels of noise are equivalent to 1 knot of speed, and these are the relative importance factors needed. The boat is then selected as illustrated in table III. Calculations of value from data follows:

V (#1) = (25 x 4) - (80 x 1) = 20
V (#2) = (20 x 4) - (50 x 1) = 30

Note that speed adds to the boat's value, noise subtracts. The above assessment indicates the choice of Boat #2. It's a slower boat but its reduced noise makes it more effective by the criteria established. This sort of assessment might be done to determine operational capabilities, to determine design criteria, or in resource allocation determine the appropriate levels of effort in the two technological areas of boat power and noise reduction.

Who Assesses Technology and Why--Or For What Purpose? Intuitively, nearly everyone assesses technology at some time, for some purpose, and to some degree of sophistication. The "man on the street," for example, may essentially assess the aggregates of the technologies of color versus black and white television. He may consider the collective value of parameters such as cost, picture quality, repair frequency, and pressure from his wife in order to choose which, if either, to buy. That nearly everyone has different values was pointed out by Willian D. Guth and Renato Tagiuri which emphasized the following points.[18]

-The personal values that businessmen and others have can be usefully classified as theoretical, economic, aesthetic, social, political, and religious.

-The values that are most important to an executive have profound influence on his strategic decisions.

-Managers and employees often are unaware of the values they possess and also tend to misjudge the values of other.

TABLE I

Basket #1	Fruit Cost (¢/unit)	Basket #2
5 apples	10	10 apples
8 oranges	20	2 oranges
6 bananas	30	9 bananas

TABLE II

Boat #1	Importance Factor	Boat #2
25 K		20 K
80 db		50 db

TABLE III

Boat #1	Importance Factors (db/kts)	Boat #2
25 K	4	20 K
80 db	1	50 db

-The executive who will take steps to better understand his own values and other men's values can gain an important advantage in developing workable and well-supported policies.

Earlier it was stated that the assessment of technology depends on who assesses, why the assessment is undertaken, and on the nature of technology itself. A hypothetical situation which provides some illustration of the range of assessors, and how assessment might vary over this range is provided in the following example. This example also illustrates one of the difficulties in assessing technology which results from variations of people and purposes involved.

Consider the technology of batteries and three of its parameters: volume, cost, and time between recharging. A broad range of assessors might be the following in the situations described.

Technology Involvement	**Situation**
User	Lieutenant, USN: Commanding Officer of a boat, which contains batteries; drifting on a Vietnamese river on night patrol.
R&D Manager	Chief of Naval Development; responsible for Navy's total Exploratory Development Program (Applied Research) considering each year's fiscal budget.
Boat Designer	Naval Architect, Naval Ship Systems Command, designing a boat for use in Vietnam.
R&D Engineer	Project engineer; working in a Navy R&D lab to improve the general performance of batteries.

These four people might assess battery technology using the same quantitative techniques, where 10 is the highest value that may be assigned and 0 the lowest, as shown in table IV.

Table IV shows the relative importance factors that the four persons might assign to the parameters based on intuition. The differences shown by the variations of relative importance are possibly true, while perhaps exaggerated. The importance factors were chosen considering the following rationalizations.

The boat operator's life depends to a large extent on his boat. He's probably very concerned when, in the situation described, he must start-up his *loud* engines to charge the batteries. He therefore considers the necessity and the time between recharging very important. He's probably not too concerned with the volume of the batteries so long as they don't infringe significantly on ammo storage space. He probably doesn't care what the batteries cost, much less the cost of the battery R&D effort.

The R&D manager is likely to place more importance on cost and less importance on individual performance characteristics. This is probably due to his responsibility for a large number of R&D programs and proposed programs involving many different parameters of many different technologies and the common element among these is cost.

The boat designer is concerned with the overall performance of the boat. He must assure that all components required fit onto the boat, and he therefore considers volume relatively more important than cost or time between recharging.

The project engineer is concerned with many characteristics of batteries; he is concerned with the improvement of batteries in general. It is not particularly required of him that he produce a profit. Therefore he may not be particularly cost conscious. It is not required of

TABLE IV

TECHNOLOGY: BATTERIES

Parameter	User	Manager	Designer	Engineer
Volume	3	2	10	8
Cost	0	10	2	2
Time between Recharging	10	2	4	1

him, perhaps, that he produce the smallest possible boat battery, and therefore he places less importance on volume than the boat designer does.

The above considerations suggest that the selection by a person of relative importance factors for parameters describing a technology is highly influenced by the environment in which the person is involved. Key expressions taken from the above for the persons described are:

User: life, Vietnamese river (warfare)

Manager: total R&D program; command

Designer: performance of boat (system made up of many technologies); engineering center

R&D many characteristics of one technology; laboratory

A difficulty in assessing technology, illustrated above, is the problem of obtaining and maintaining an alignment of relative importance factors between the users of technologies and those responsible for improving the capabilities of technologies.

In the *hypothetical* example, the R&D engineer may not have been aware of the degree of importance of a particular parameter to a particular user. In other words, an R&D engineer may not recognize the need for a particular technological improvement. The importance of such need-recognitions as it contributes to the successful development of weapon systems is well illustrated by the comprehensive technology source study Project HINDSIGHT conducted by Col. Raymond Isenson and Dr. Chalmers Sherwin of the Department of Defense.[19]

R&D Programming. To reiterate, three factors used by the U.S. Department of Defense to evaluate systems programs are "military utility," "technical feasibility," and "financial acceptability." These factors are also important when planners evaluate research and development. However, it is necessary to quantize these factors so that they may be compared for different research and development programs.

One of the simpler techniques being investigated by the Navy utilizes Appraisal Sheet No. 1 which addresses the problems of military utility. Military utility with respect to development atmosphere is a measure of R&D work in terms of its usefulness in meeting U.S. Navy's General Operational Requirements (GOR). To be useful, hardware or information must provide a new or improved capability in the shortest possible time after its need is recognized. Thus, military utility is made up of three interdependent criteria: value to naval warfare, responsiveness, and timeliness. In this condensed version, we will consider "value to naval warfare."

This criterion considers the extent of the contribution of a task area objective (TAO), a unit of work, in terms of its inherent value as well as its military operational value. The importance of a task is measured by its relative impact on any individual naval warfare category as well as the number of categories receiving a contribution from the task objective. This is done by multiplying the assigned value of the warfare category by the impact value of the contribution to arrive at a value for each individual category. The sum of these values will determine the value of the task area objective.

Note: The figures of merit, or point values assigned to each naval warfare category (column 1) are dummy figures; they were assigued for this example only. The actual total uumber of points assigned these 29 naval categories are equal to 100, and they are assigned for test purposes on the basis of the importance of each of these categories in the 1975 and 1980 time frame since this is when most of our current exploratory development work will find its way into the fleet. The operational users provided the test figures based on the preseut world situation and their estimates of the most probable future situations.

When the warfare area specialist filled in column 2, the impact of the task area objective contributions, he considered the descriptors at the bottom of the page (Scale of Definitions). In some cases the four descriptors do not adequately describe the contribution; in those cases he interpolates between these numbers.

The credibility of the ratings of technical feasibility and the probability of success increase if they are rated by personnel who have the necessary technical expertise and competence, as they can best judge these factors on the basis of the ability and experience of the individuals and/or organizations carrying on the development efforts under consideration.

The top half of Appraisal Sheet No. 2 solicits the opinion of the technical specialist regarding the probability of achieving the total task area objective that is being undertaken. It considers whether the task could be successfully accomplished from a scientific and technical feasibility point of view. Technical risk also takes into consideration the degree of confidence or prediction that the remaining portion of the total objective can be attained. The degree of confidence or prediction that the remaining portion of the total task objective can be attained usually assesses the factors of the present state of the art, either implicit or explicit. This technical appraisal is naturally based on technical forecasts and includes time factors and resource levels, as well as the competeuce of the investigating team.

Therefore, the technical specialist checks the box that best describes his opinion regarding the task area objective being evaluated, as well as the number of different concurrent approaches being taken which are also a measure of probability of success.

The area called "sacred cow?" and "who says?" was also considered in what we call the "management environment." This section solicits opinions on the acceptability of the effort in the management structure. Here, the evaluator is asked to give what he believes to be "the Washington environment" considerations concerning this effort, and he checks the applicable box.

The bottom of Appraisal Sheet No. 2 is then analyzed. The total program is calculated by Value, Expected Value, and Desirability Index for three

APPRAISAL SHEET NO. 1

VALUE TO NAVAL WARFARE

Column 1 - Categories General Operational Requirements (GORs)		Column 2 Impact of Task Contributions 1.0	.9	.8	.7	.6	.5	.4	.3	.2	.1	Column 3 Value to Individual Category
31	STRIKE WARFARE											
6	Airborne Attack											
3	Surface Attack											
5	Submarine Attack											
4	Amphibious Assault											
7	Sea Based Strategic Deterrence											
3	Airborne Anti-Air Warfare											
3	Surface Anti-Air Warfare											
31	ANTISUBMARINE WARFARE											
5	Airborne ASW				✓							3.5
4	Surface ASW						✓					2.0
5	Submarine ASW						✓					2.5
10	Undersea Surveillance								✓			3.0
2	Mining											
3	Mine Countermeasures											
2	ASW Ancillary Support									✓		0.4
23	COMMAND SUPPORT											
3	Command and Control											
4	Naval Communications											
4	Electronic Warfare											
1	Navigation											
4	Ocean Surveillance											
5	Reconnaissance & Intelligence											
1	Environmental Systems											
1	Special Warfare											
15	OPERATIONAL SUPPORT											
2	Logistics											
4	Personnel											
2	Astronautics											
2	Aviation Support											
2	Ship Support											
2	Ordnance Support											
1	NBC Defense											

4. TOTAL VALUE TO NAVAL WARFARE = 11.4

Scale of Definitions for "Impact of Task Contribution" (Column 2):

Points - Descriptors

1.0 Creation of radically new mission concepts (meets overriding critical need)
.7 Revolutionary extension of capabilities
.4 Incremental or marginal improvement of capabilities
.2 Increase in economy

APPRAISAL SHEET NO. 2

Probability of Success

☐ 80 - 100% Chance of Meeting TAO.

☑ 30 - 80% Chance of Meeting TAO.

☐ 0 - 30% Chance of Meeting TAO.

Number of Different Concurrent Approaches

☐ 1	☐ 3	☐ 5	☐ 7	☐ 9
☐ 2	☑ 4	☐ 6	☐ 8	☐ 10 or more

Sacred Cow? Who Says?

S-1 ☐ President	S-4 ☐ ASN (R&D)(Asst Secretary of Navy for Research and Development)	S-7 ☐ CND (Chief of Naval Development)
S-2 ☐ Congress		
S-3 ☐ DOD (Department of Defense)	S-5 ☐ JCS (Joint Chiefs of Staff)	S-8 ☐ Other ______
	S-6 ☐ CNO (Chief of Naval Operations)	

Appraisal Summary

No. of GORs 5

Value (V) 11.4

Probability of Success (Ps) 0.9375

Expected Value (EV) 11.4 x 0.9375 = 10.7

Optimum Funding 2 Million

Desirability Index (D) 5.35

funding levels, by the computer. The inputs for military utility come from Appraisal Sheet No. I.

For example: Suppose the proposed task area objective (TAO), or R&D effort, is to devise a system able to detect submerged submarines a given distance away from a sensor, say 20 miles. We shall consider the criterion "Value to Naval Warfare." Of the 29 naval General Operational Requirements shown in Column 1 of Appraisal Sheet No. 1, the TAO would be of value and contribute only to five GOR's: Airborne ASW, Surface ASW, Submarine ASW, Undersea ASW, and ASW Ancillary Support.

With respect to airborne ASW, the success of the R&D venture in this hypothetical example is considered a "revolutionary extension of capabilities, and is accorded 0.7 point. At the same time, airborne ASW is said to contribute 5 out of the 100 units assigned to all the GOR's. Thus, the value of the TAO to naval warfare with respect to airborne ASW is 0.7 x 5 = 3.5. The other categories can be similarly evaluated for their contributions, and the total value of this TAO to naval warfare is summed at 11.4, as shown on the appraisal sheet.

For our calculation of the Probability of Success (P_s) in meeting the TAO, we use the probability chart shown on table V. In this chart, n is the number of concurrent approaches used to accomplish the TAO, and C is a number arbitrarily assigned to the chances of succeeding in a given approach. We use:

80 - 100% chance of success: C = 0.8

30 - 80% chance of success: C = 0.5

0 - 30% chance of success: C = 0.2

We assume that all approaches n have the same chance of success, and therefore the same value of C. If each n were to have a different C, a more involved calculation would have been necessary.

The number assigned to the probability of one approach failing is then $(1 - C)$.

The number assigned to the probability of n approaches failing is $(1 - C)^n$.

Further, if we assume that at least one of the approaches taken will succeed, then the number assigned to the probability of success Ps is $1 - (1 - C)^n$.

This figure for Ps is filled in on Appraisal Sheet No. 2 under the Probability of Success column.

Example: On an Appraisal Sheet No. 2, we might have had 4 approaches (n = 4) with a 30-80% chance of meeting TAO (C - 0.5). Then the number corresponding to the probability of success is 0.93750 or 93.75 per cent. From our previous example we calculated the total value of a given TAO to be 11.4. Therefore, the expected value is 11.4 x 0.9375 = 10.7.

The preceding has been a discussion of concurrent approaches. If the task area were made up of phased or sequential operations, these probabilities would be handled in a different manner.

Three funding levels are utilized in the "concurrent" approach: the actual/optimum, maximum, and minimum.

The actual/optimum consists of the latest approved fiscal data. For each subsequent year, funds are entered

TABLE V

TABULATION OF P_S

n \ C	0.8	0.5	0.2
1	0.80000	0.50000	0.20000
2	0.96000	0.75000	0.36000
3	0.99200	0.87500	0.48800
4	0.99840	0.93750	0.59040
5	0.99968	0.96875	0.67230
6	0.99993	0.98438	0.73786
7	0.99997	0.99219	0.79029
8	0.99999	0.99609	0.83223
9	0.99999	0.99805	0.86578
10	0.99999	0.99902	0.89263

based on what is estimated as necessary to achieve the completion date if the task area is supported at an optimum rate. An optimum rate is one which permits aggressive prosecution using orderly developmental procedures--not a crash program.

The maximum consists of what could effectively be expended in advancing task area completion date. Maximum funding is the upper limit in which unlimited resources are assigned in order to accelerate the accomplishment of a task area.

The minimum consists of what could be effectively utilized to maintain continuity of effort and some progress toward fulfilling the task area objective. Minimum funding is the threshold limit below which it would not be feasible to continue further efforts in the task area.

The simplified formula is:

VALUE (V) X PROB OF SUCCESS (P_s) = EXPECTED VALUE (EV)

$$\frac{\text{EXPECTED VALUE (EV)}}{\text{FUNDING LEVEL (C)}} = \text{DESIRABILITY INDEX (D)}$$

Finishing up the analysis of the rating sheet, "GORs" represent the number of general operational requirements affected by the project; "Ps" as previously stated, is read off a probability chart; and the optimum funding level is determined according to the resources needed to complete the project in the time span of the study. The final desirability index numbers now provide a way to compare a great multitude of current and proposed R&D projects. By carrying out similar evaluations on the basis of responsiveness to expected needs, the timeliness of the projects, and other criteria, it is possible to combine all the information about the project and come up with its "total warfare value."

The end results of a research and development planning effort like this are computer printouts (figures 4 and 5) which rank every project according to its value in the overall program. In the Navy this comes to over 700 separate R&D projects. It would be a mistake, however, to think that the impressive-looking computer printouts are taking over the final decisionmaking job. Most of those who design and work with information systems like the one described fully realize that technological forecasts and quantitative estimates of project value are no more or less than a planning tool--and only one of many that a manager must use in making final decisions.

Conclusions. I am well aware of many of the omissions and weaknesses of these quantitative selection or resource allocation techniques. It should be stressed again that they were not intended to yield decision, but rather information which would facilitate decision. Indeed, these techniques are merely thinking structures to force methodical, meticulous consideration of all the factors involved in resource allocation. *Data* plus *analysis* yields *information. Information* plus *judgment* yields *decisions.*

Data + Analysis = Information

Information + Judgment = Decision

I am firmly convinced that if I had to choose between any machine and the human brain, I would select the brain. The brain has a marvelous system that learns from experience and an uncanny way of pulling out the salient factors or rejecting useless information. It is wrong to say that one must select intuitive experience over analysis or minds over machines; really they are *not* alternatives, they complement each other. Used together, they yield results far better than if used individually.

A close look at a few "facts" concerning the quantitative resource allocation methods shows these approaches to be merely experimental management techniques. The fact that a computer or an adding machine may be used to facilitate data handling should in no way distract from the basic fact that

NAVMAT PROGRAM EVALUATION REPORT

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(RANKING OF 65248012 BY TOTAL WARFARE VALUE MR. CETRON 69TPG)

26 APR 1967

TASK AREA NUMBER	TITLE	SC	EXP. VALUE	FUNDING MAX	CUM	OPT	CUM	MIN	CUM	RANKING*
WF11511751 WF0190101	(U)SPACE SYSTEMS ENGINEERING		26.446875	300	300	300	300	300	300	27.3
XF03222001 XF0190204	(U)COMMUNICATIONS SATELLITE SUPPORT		22.050000	2000	2300	1375	1675	1000	1300	25.2
WF03222751 WF0190101	(U)SATELLITE COMMUNICATIONS		16.350000	350	2650	350	2025	0	1300	21.8
WF12552751 WF0190202	(U)SATELLITE OCEANOGRAPHIC DATA COLLECTION		9.375000	900	3550	700	2725	150	1450	12.5
WF12551752 WF0190202	(U)SOLAR RADIATION MONITORING SATELLITE		8.000370	3000	6550	2800	5525	1200	2650	11.9
WF03232751 WF0190101	(U)SATELLITE NAVIGATION			2250	8800	2250	7775	0	2650	10.2
WF12551751 WF0190202	(U)METEOROLOGICAL SATELLITE DATA READOUT		8.750000	600	9400	200	7975	150	2800	10.0
WF02112751 WF0190102	(U)ADVANCED TECHNIQUES FOR SPACE OBJECT DETECTION AND IDENTIFICATION		2.800000	850	10250	850	8825	0	2800	5.6
WF02111752 WF0190202	(U)OCEAN SURVEILLANCE SYSTEMS ANALYSIS			5500	15750	5000	13825	4000	6800	4.8
WF05311751 WF0190102	(U)SATELLITE INTERCEPTER SYSTEMS ANALYSIS			500	16250	500	14325	200	7000	1.0
WF05372751 WF0190102	(U)ASTRO-DEFENSE THREAT STUDIES			300	16550	200	14525	100	7100	1.0

Fig. 4—Example: Computer Printout Ranked by Warfare Value and Expected Value

DUMMY DATA

86081260001

C NAVMAT PROGRAM EVALUATION REPORT

(RANKING BY OPT DESIRABILITY)

TASK AREA NUMBER	TITLE	SC	FUNDING MAX	CUM	OPT	CUM	MIN	CUM	RANKING*
SF08452002	(U)ACOUSTICAL SILENCING (INTERNAL SHIPS SYSTEMS)	S6	320	320	220	220	185	185	.266477
SF08452004	(U)ACOUSTICAL SILENCING, SHIP ISOLATION DEVICES	S6	535	855	435	655	333	518	.181034
XF10532001	(U)TEST EQUIPMENT	S3	2400	3255	1300	1955	770	1288	.124614
SF08452005	(U)ACOUSTICAL SILENCING, HULL VIBRATION AND RADIATION	S6	955	4210	680	2635	610	1898	.093750
SF02132001	(U)DIRECT VIEW IMAGE INTENSIFIER TECHNIQUES	S4	400	4610	300	2935	65	1963	.080000
SF08452001	(U)SHIP SILENCING MEASUREMENTS, ANALYSIS AND PROBLEM DEFINITION	S6	1360	5970	1095	4030	860	2823	.072602
WF02132601	(U)IMAGING RECONNAISSANCE SENSOR DEVELOPMENT	S3	1000	6970	750	4780	200	3023	.056666
RF08412002	(U)DEEP RESEARCH VEHICLE PROGRAM	S6	1700	8670	1510	6290	1180	4203	.048344
SF01121003	(U)DOMES AND SELF NOISE	S6	600	9270	550	6840	540	4743	.041236
XF10545001	(U)ADVANCED ACTIVE DEVICES AND TECHNIQUES	S3	4000	13270	2600	9440	2000	6743	.039711
PF11521004	(U)IMPROVED NAVY STAFFING CRITERIA	S6	500	13770	500	9940	253	6996	.038400
SF01121007	(U)SYSTEM ANALYSIS AND ENGINEERING	S6	1000	14770	850	10790	500	7496	.037058
SF08452003	(U)ACOUSTICAL SILENCING, EXTERNAL SHIP SYSTEM	S6	1920	16690	1735	12525	1412	8908	.033789
TF10531001	(U)CARGO MOVEMENT AND DISTRIBUTION	S6	700	17390	550	13075	300	9208	.018039
SF01121004	(U)TRANSDUCERS AND ACOUSTIC POWER GENERATORS	S6	4500	21890	4009	17084	2700	11908	.011785
SF01121002	(U)SONAR SIGNAL PROCESSING AND CLASSIFICATION	S6	7000	28890	6520	23604	5800	17708	.007246
SF01121001	(U)UNDERWATER SOUND PROPAGATION	S6	6400	35290	6000	29604	4800	22508	.005250
SF09443004	(U)NUCLEAR PROPULSION PLANT MATERIALS DEVELOPMENT	S4	1100	36390	1100	30704	0	22508	
SF09443001	(U)NUCLEAR PROPULSION PLANT TECHNOLOGY	S4	1000	37390	1000	31704	0	22508	
SF09442003	(U)SURFACE SHIP REFUELING EQUIPMENT AND PROCEDURES DEVELOPMENT	S4	2200	39590	2200	33904	0	22508	

DUMMY DATA

Fig. 5–Example: Computer Printout Ranked by Desirability

human subjective inputs are the foundation of these systems. Accurate human calculation, as opposed to use of a computer for the calculations of all the interrelationships considered, would not alter the basic principles of these management tools in any respect. Yet, I often hear the reactionary complaint that quantitative measurements cannot be applied to management processes because human judgment cannot be forsaken, and machines cannot replace the seasoned experience expertise of the manager.[20]

The real concern should be directed toward using the collective judgment of technical staffs (technological forecasts) and decisionmakers in such a manner that logically sound decisions are made, greater payoff is achieved for the resources committed, and that less, not more, valuable scientific and engineering time expended. To make an incorrect decision is understandable, but to make a decision and not really know the basis for the judgment is unforgivable. The area of good resource allocation certainly must have advanced beyond this point; otherwise, a pair of dice could replace the decisionmaker.

Most of the managers who design and work with information systems fully realize that technological forecasts, quantitative estimates of project value, and other aids to resource allocation are merely a planning tool--and only one of a brand new kit of advance decisionmaking devices.

Even this caveat, however, does not defuse critics of the whole idea--and there are some very vocal ones around in government and business. Some of the criticism is in reaction to the fear of "mechanization" of a task felt to be rightfully in the province of human evaluation. Other critics claim that building up a logical system, computerizing the output, and quantifying what are essentially intuitive and judgment decisions may insulate some managers with a false sense of security. The validation of the process will not be continued, and management responsibility will be abandoned. Another criticism stems from the use of estimates as basic figures in the analysis. This kind of objection can also be applied to decision based on "experience" and made without a quantitative approach.

Technological forecasting and systematic analysis tend to force managers to consider their resource allocation tasks more comprehensively and highlights problem areas that might easily be overlooked by more traditional ap-

BIOGRAPHIC SUMMARY

Mr. Marvin J. Cetron is the Head of the Technological Forecasting and Appraisal Group, Exploratory Development Division, in the Headquarters of the Naval Material Command. He has been engaged in various technological planning roles in laboratories, Navy Headquarters and in the Department of Defense for more than 15 years. He served as Head of the Planning Branch at the U.S. Naval Marine Engineering Laboratory; Engineering Assistant to the Technical Director of the Navy Applied Science Laboratory; and Head of the Management Planning Review Branch of the Applied Science Laboratory. He is a member of the Military Operations Research Symposia, the American Institute of Industrial Engineers, The Interservice Technological Forecasting Methodology Group, the Interagency Group for Research on Research, and the American Association for the Advancement of Science.

Mr. Cetron has worked with various government agencies both in this country and abroad, lectured at many academic institutions and to many professional groups. He has published numerous articles, coauthored several books, and contributed chapters to other books on long range planning, technological forecasting, and operations research in R&D.

He hold the B.S. degree from Pennsylvania State College, the M.S. degree from Columbia University, and is currently completing the requirements for the Ph.D. degree in R&D Management at American University.

proaches. However, regardless of the high degree of sophistication being attributed to these planning devices, managers should use them with caution.

FOOTNOTES

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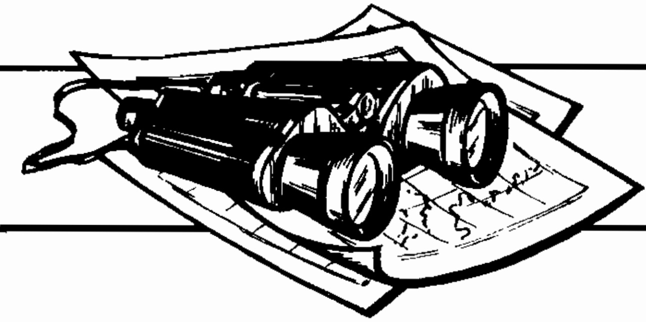
If I must choose between peace and righteousness, I choose righteousness.

Theodore Roosevelt, 1858-1919,
Unwise Peace Treaties



NEW HORIZONS

(This new section of the *Naval War College Review* has been established in a further effort to stimulate imaginative thinking on the problems facing the Navy and the nation. "New Horizons," which will appear periodically in the *Review*, will serve as a vehicle for short articles embodying ideas and concepts currently under study and research at the Naval War College. They are offered not as finished products of research, but as essays to stimulate discussion and comment and therefore do not reflect in any way the official position of the Naval War College or the Navy Department, Ed.)

AN INDIAN OCEAN ANZUS SQUADRON

By the end of 1971 the British naval presence, which has dominated the Indian Ocean basin for over a century, will cease to exist. This withdrawal will leave in its wake a power vacuum alarmingly similar to that created in the Middle East by the removal of British land forces from Palestine. The nations east of Suez, many of them newly independent, militarily weak, and politically unstable, will be exposed to the dual peril of internal turmoil and external pressure--particularly from Communist nations.

A nuclear menace posed by Communist China would increase enormously the pressures for nuclear proliferation, particularly in the case of India, which has so far foresworn nuclear weapons. Some U.S. allies--specifically Thailand--are already visibly nervous over U.S. intentions when the Vietnam conflict is finally ended.

The prospect of a possible U.S. withdrawal from Southeast Asia, coupled with that of a Red China internally stable and capable of moving aggressively on the international scene, is as threatening as it is plausible. Red China will be free to look afar--particularly at the attractive potential of the many countries bordering the Indian Ocean. To this may be added the clear demonstrations of Russian interest and intentions in the region. Soviet naval vessels based as far away as Murmansk and Vladivostok already roam the vicinity, despite logistics problems made more complex by the closing of the Suez Canal. All indications are that the U.S.S.R. now plans to replace the British as the major naval power, with a permanent force in being, in the Indian Ocean area.

It is possible that the United States might determine to maintain a substantial permanent naval force in the area to counter such a Russian challenge. But the clear trend in foreign policy thinking in the United States would appear to lead away from any further overseas involvement and "entangling" commitments even to old areas of responsibility, much less to a new area such as the Indian Ocean. The statement has repeatedly been made, "The United States should not be the unilateral policeman of the world." Moreover, the cost of maintaining a balanced force of any size in that area would be eminently unpopular in the aftermath of the expensive Vietnam experience.

And yet let us consider for a moment the potential consequences which could ensue if the free world were to abdicate from the Indian Ocean. In the Mediterranean the U.S.S.R. has pursued a manifold strategy combining a substantial naval presence (complete with amphibious capabilities), military and economic aid to selected states, and overt political support for local nationalist causes. The result has been that Syria, the U.A.R., and Algeria are now palpably contained in the sphere of Soviet influence. Might not the policy which has functioned so admirably in the northern tier of Africa meet with equal success in littoral East Africa, in the Red Sea, in the Persian Gulf, and even in those chief prizes of South Asia--India and Pakistan? The circumstances which might lead to enlarged Soviet influence are not difficult to imagine.

In 1964 the British commando carrier H.M.S. *Centaur* was cruising with two destroyers off the coast of East Africa when a message was received from the Ministry of Defense in London--"Capture the Tanzanian Army." The army had mutinied, and President Nyerere had asked the British for help. Only hours later *Centaur* was off Dar es Salaam, the Tanzanian capital. By the following nightfall, *Centaur's* commando forces of Royal Marines which had been lifted ashore by helo had completed their mission. The commanding officer was able to dispatch the message--"Tanzanian Army captured; in barracks." In 1972, with the British replaced by a Soviet presence, to whom will a desperate East African president or premier be likely to apply for assistance?

Under these circumstances the question is raised as to how the challenge can be met--to avoid leaving this broad area, one seventh of the world's surface, to Russian (and possibly Communist Chinese) domination. Specifically, how could the British military presence be replaced with a substitute free world force?

The following three factors would seem to be inherent in any solution involving the United States:

a. It must be clearly based on a solid international partnership.

b. It must be established on an equitable cost-sharing basis that would not impose inordinate expenses on the United States.

c. It must be flexible enough to permit partner nations to detach and operate unilaterally where necessity requires.

One proposal which would seem to meet the case is the establishment of a squadron combined of United States, Australian, and possibly New Zealand components with the express purpose of cruising the region at issue. For purposes of this discussion it is assumed that New Zealand would support the establishment of this squadron but would not actively participate because of limited forces available.

The force would comprise an attack type aircraft carrier, provided by the United States, and two escort destroyers and an oiler furnished by the Royal Australian Navy, all to be homeported somewhere in Western Australia--possibly at Fremantle. The carrier need not be a modern CVA; it would fully suffice to remove from mothballs a ship of the *Hancock* class and equip and man it for multiple purposes, perhaps with the designation CVM. Its air group might be composed of two attack squadrons, a defensive fighter-interceptor squadron, an augmented troop helo squadron, and suitable auxiliary aircraft. A reinforced company of marines, transportable by helicopter, would also be aboard with their supporting arms and equipment. The carrier would be U.S. manned; the escorts and oiler would be RAN manned. The squadron commodore and staff in the carrier would be bi-national with a U.S. flag officer in command and with an Australian Chief of Staff.

If the need ever arose, it would be perfectly feasible at short notice to remove the Australian personnel from the carrier to allow unilateral action by either country. This capability would always exist, even though all regular missions would be undertaken on the basis of full concurrence between the two nations involved.

At the economical speed of 17 knots, the Anzus Squadron could leave Fremantle and in 40 days visit, for example, Tamatave in the Malagasy Republic, Mombasa in Kenya, Jidda, Karachi, and Bombay. Without appreciably extending the cruise time, underway visits could be scheduled to several other ports as politico-military expedients demanded. With five cruisers a year, the squadron could make an appearance in a port or off the coast of every nation in the Indian Ocean basin, stopping several times annually at key points. In contingency situations the force would be positioned as necessary to meet the need.

Cost sharing would be inherent to the bi-national concept of the Anzus Squadron: operating costs to the United States would be limited to those relating to the carrier. Australia, which would support all expenses incurred by her own naval units, might reasonably partially offset any gold flow problem associated with U.S. personnel and dependents living there with compensatory purchases in the United States.

Moreover, those costs which the United States would have to bear could be minimized in several ways. The recommissioned carrier would involve only standard operational costs of personnel, current ship maintenance, and fuel. In the light of the squadron's mission, its aircraft could well be taken from obsolescent existing stocks scheduled for replacement, rather than new, high performance, expensive models. The RAN oiler would provide for underway fueling. Currently available 7th Fleet replenishment forces--perhaps rendezvousing with the U.S. carrier in the Malacca Straits or Bay of Bengal area on each of its five cruises--should be ample to supplement the main logistic support of Australian Navy shore activities. Spare parts and technical support could be provided through the line of communication (LOC) between CONUS and the Naval Communications Station, Harold E. Holt, at North West Cape, on the coast north of Fremantle.

Homeporting the squadron in Australia would obviate a backup carrier or carriers which would otherwise be needed for rotation--since short, periodic overhauls in an Australian shipyard might well keep the carrier almost continuously operational. These overhauls would be austere, without any expensive modernization being required. If after 2 or 3 years a major overhaul became necessary, the CVM could be temporarily relieved for the period necessary by another U.S. carrier due for decommissioning. No commissary or exchange facilities would be needed. The Australian economy should well suffice to meet the needs of U.S. personnel. The permanent, bi-national character of the mission would clearly be reinforced by Australian homeporting, since close personal relationships, mutual understanding, and friendly cooperation would be sure to result. This association with a Commonwealth country is particularly attractive for political and psychological reasons because 11 nations in the Indian Ocean are are members of the Commonwealth. U.S. partnership with a major indigenous country of the area would make the U.S. permanent military representation there more acceptable than a U.S. unilateral presence.

The image of the Anzus Squadron could thus be projected as one of reassurance and goodwill, with the ready capability for missions of peacekeeping and politico-military importance. It could stand off the East African coast in situations similar to the Congo, evacuating personnel as necessary with its large troop helicopters; when requested, it could come swiftly to the assistance of a government in distress as H.M.S. *Centaur* did in 1964; serving as a strike carrier/assault force, airfields could be seized and held for landbased air to arrive under extreme emergencies; it could be a "holding force" in some situations until major 7th Fleet or Strike Command forces might arrive on the scene; and, above all, the squadron could quietly demonstrate its flexible strength to states in need of reassurance by continuous visits throughout the region. Its nuclear retaliatory capacity could be dealt with in low key or not at all, as circumstances indicated.

In such a manner the power void created by the British withdrawal east of Suez could be decisively and permanently filled by free world powers without great expense to the United States and without the risk of accusations of imperialistic self-interest. External threats to indigenous countries would be effectively deterred and a stabilizing influence applied to the political and social turmoils of internal unrest so common in the area. The Anzus Squadron would represent a tangible, credible, friendly military presence to such Middle Eastern states as Iran and Saudi Arabia to counter any potential pressure from the U.A.R. or U.S.S.R. Threats of Chinese Communist nuclear blackmail would be effectively neutralized, lessening tension and ameliorating the climate for nonproliferation. And lastly, a constraining influence could be exerted on the perennial altercations between India and Pakistan.

There would appear to be many advantages and benefits in establishing an Indian Ocean Anzus Squadron. The only alternative might well be to offer an almost irresistible incentive to Russia or Communist China to step into the void created by the British withdrawal, unchallenged, and to relinquish the region to the instability which promises to plague it for a long time to come.

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Never tell people how to do things. Tell them *what* to do and they will surprise you with their ingenuity.

George S. Patton, Jr.: War As I Knew It
1947